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January 12, 2000

Magalie Roman Salas
Secretary
Federal Communications Commission
445 Twelfth Street, S.W.
Washington, D.C. 20554

Re: Notification of Ex Parte Presentation in MM Docket No. 99-25

Dear Ms. Salas:

On January 11, 2000, the undersigned, David Wilson and Dr. Charles Jackson met with Tom Power of Chairman Kennard's office. The purpose of the meeting was to present Dr. Jackson's report that he prepared as part of the National Association of Broadcasters ("NAB") reply comments in MM Docket No. 99-25 filed November 15, 1999.

The report compared the four receiver studies submitted in MM Docket No. 99-25. The report discussed the differences and similarities between the four studies, compared the data from each and ultimately concluded that all four receiver studies support the view that relaxing the FCC's adjacent channel protection ratios would create increased interference in the vast majority of existing FM receivers when measured by consumer preferences.

During the meeting, several items were distributed to Mr. Power. A copy of each is attached. Included is a CD-ROM of the presentation that contains several audio files that demonstrate the effects of noise and interference using a variety of music and levels.

Any questions should be referred to the undersigned.

Respectfully Submitted,

Lori Holy

Attachments

cc: Tom Power

A Review of Four Studies of FM Receiver Adjacent-Channel Immunity

By

Dr. Raymond L. Pickholtz

Dr. Charles L. Jackson

November 1999

The Question

- We also seek comment on the state of receiver technology and the ability of receivers to operate satisfactorily in the presence of 2nd-adjacent channel protection.
  - NPRM 99-6 at 46.

The Studies

- Office of Engineering and Technology (OET) of the FCC,
- the NAB,
- the National Lawyers Guild (NLG),
- National Public Radio together with the Corporation for Public Broadcasting (CPB) and the Consumer Electronics Manufacturing Association (NPR et al.).

Summary of Results

Criterion: the fraction of radios that receive harmful interference from 2nd-adjacent channel signals at the FCC limit.

- NPR et al. 81% (13 of 16 receivers)
- NLG 27% (3 of 11 receivers)
- OET 10% (2 of 21 receivers)
- NAB 79% (22 of 28 receivers)

Policy Conclusions

- NAB/NPR — You should not relax the constraints on 2nd-adjacent channel signal levels to accommodate low-power FM.
- OET/NLG—You don't need to worry about 2nd-adjacent channel signal levels when thinking about low-power FM.

National Lawyers Guild

- "Of the receivers tested, about half performed dramatically better than the FCC ratios would suggest. The performance of the other half varied widely but averaged out at approximately the level of the current FCC interference ratios."

  – NLG Comments, at XII(B)

NAB

- "Second and third adjacent channel protection is still necessary"
  - NAB Comments, p. II

Test Environment

- Parties used similar test equipment and procedures.
  - Three of the four groups used the same measuring instrument.
- FM receivers and FM-receiver testing are mature technologies—there should be no surprises.

Environment (Continued)

- The relevant laws of physics should be the same whether in Columbia, MD, Boston, Cleveland, or anywhere else in the U.S.
- All four groups tested reasonably similar selections of radios, although some groups tested more than did other groups.

What Did the Groups Do Right?

- The Gold Standard of audio testing is listening tests, but these are expensive.
- The general design of the test methods appears to have been appropriate.
- There are some questions about the details of the actual testing.

What Did the Groups Do Wrong?

- All groups tested car radios.
- They failed to observe that
  - car radios operate in a different environment than do household radios; and
  - car radio test results cannot be properly combined with the test resutls for other radios.
- The NLG test procedures and results were suspect.
- The NAB report misspelled Larry Middlekamp's name.

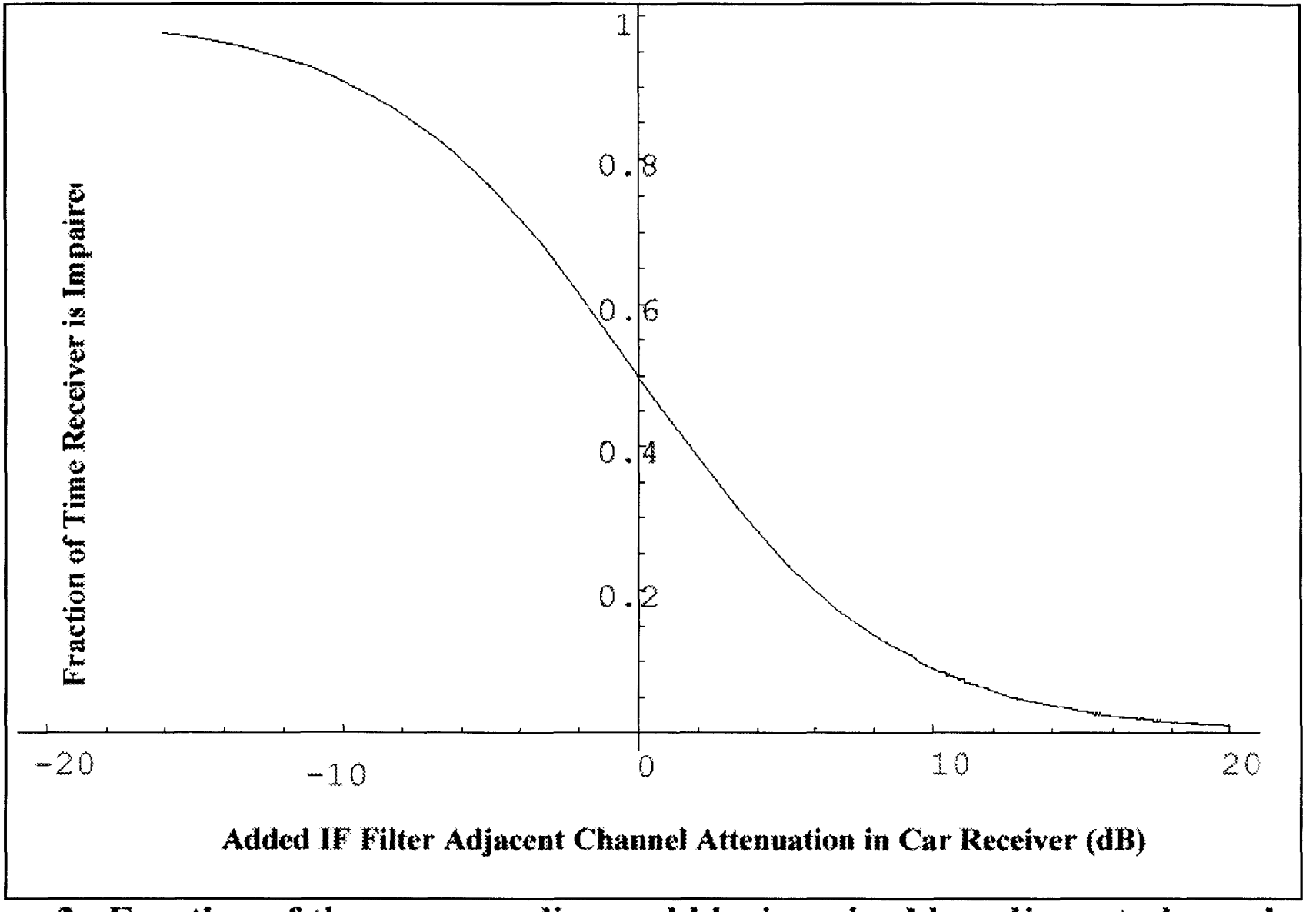

Figure 2. Fraction of time a car radio would be impaired by adjacent-channel interference as a function of changes in the IF filter adjacent channel selectivity.

Why Do the Results Differ?

- The parties used different definitions of harmful interference.
  - NLG FM threshold or about 20–30-dB SNR
  - OET 1% or 3% added distortion or about 25–30-dB SNR
  - NPR 45-dB SNR
  - NAB 50-dB SNR

The Basis for the NAB's 50 dB Standard

- FCC's apparent design standards for the FM service
- ITU-R standards (e.g., R 641, *Determination of Radio-Frequency Protection Ratios for Frequency-Modulated Sound Broadcasting*, p. 3. sets the 50-dB audio SNR as the basic test condition).

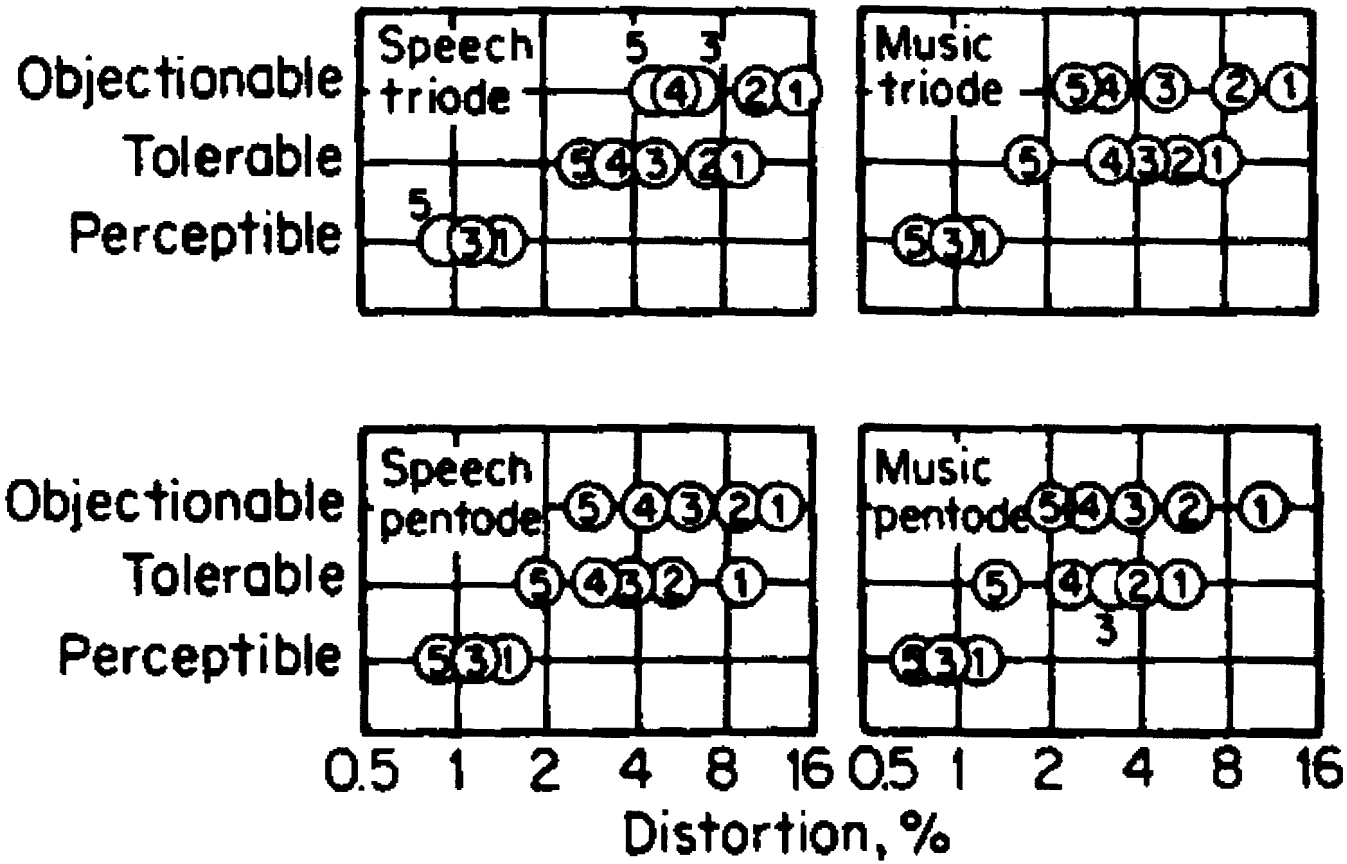

Fig. 19-35. Perceptible, tolerable, and objectionable amounts of controlled nonlinear harmonic distortion of speech and music for various high-frequency cutoffs.[31]

From Electronic Engineer's Handbook, 2nd Edition, Ed. Fink and Christiansen, McGraw-Hill, p. 19-18

Comparing the Standards

- T1 (Pure Tone 220Hz or A below middle C)
- T2 (440 Hz or A above middle C)
- T3 (220 Hz followed by 220 Hz plus 440 Hz down 40 dB)
- T5 (220 Hz followed by 220 Hz plus 2090 Hz down 40 dB)
- T6 (T1 plus white noise at -30 dB)
- T7 (Start of Mozart Symphony No. 25 K183, 2nd)
- T8 (Start of K183, 2nd, with white noise added at -30 dB)
- T9 (Johnny Cash, Ghost Riders in the Sky)
- T10 (Mozart with Johnny Cash at -30 dB)
- T11 (Ghost Riders with white noise at -30 dB)
- T12 (A22 followed by A220 plus 440 Hz at 6.5% level)
- T13 (Ghost Riders with white noise at 4.4%, unimpaired using OET +1% criterion on a Walkman with 3.5% THD)
- T14 (Ghost Riders with white noise at 6.4%, unimpaired using OET +3% criterion on a Walkman with 3.5% THD)

Harmonizing the Results

Criterion: the fraction of radios that receive harmful interference by the ITU/NAB criterion from 2nd-adjacent channel signals at the FCC limit.

- NPR et al. 100% (16 of 16 receivers)
- NLG 73% (16 of 22 receivers)
- OET 79% (16.5 of 21 receivers)
- NAB 79% (22 of 28 receivers)

TABLE 7— Condensed Ratings

Study	Rating	Receivers tested	Interference criterion	Comments
NAB	*****	28	SNR	• Well documented. • Tied test criteria to subjective tests, standards. • Explained basis for criteria. • Misspelled Larry Middlekamp's name in a footnote.
NPR et al.	*****	16	SNR	• Lots of data, but confusing organization at times.
OET	**	21	Distortion (THD+N)	• Weak documentation of procedures. • Used 1% and 3% increases in THD+N as criterion. • No testing of a significant class of receivers. • Some results are difficult to understand, e.g., Table 3, Receiver 18 (1.1-dB increase in interfering signal pushes THD+N from 1% to 3% (a 10 dB decrease in SNR). • Table 2, receiver 11, data problem.
NLG	*	11	Distortion (THD+N)	• Use of distortion (similar to OET, but without concern for starting point). • The NLG "transition zone" an ill-defined and misleading criterion. • Some strange results—greatly hamper one's ability to accept results.

Conclusions

- The laws of physics were the same for everybody, and the receivers appear to perform similarly. The differences among the studies rest primairly on how they defined *satisfactorily*.
- There are real tradeoffs here. The Commission should strive to understand them and make an informed decision.
- The FCC should have defined *satisfactorily* and asked for comment on that definition in addition to its broader question.

Perspective

- Digital Tornado
  - "Internet radio" services exist today that transmit continuous, real-time audio over the Internet. Many other sites now offer a selection of real-time audio clips that users can choose to listen to, such as news, weather forecasts, and music.
- Armstrong
  - His paper on FM was published in 1936
  - March 1939, the FCC allocated spectrum for FM broadcasting.

Waveforms to demonstrate masking and to demonstrate the effects of noise and interference at various levels

This short memo describes the development and content of a set of waveforms that demonstrate audio masking and the effects of noise and interference at various levels. The waveforms are denoted T1 through T11 to distinguish them from a similar set I prepared that were labeled S1—S10.

All waveforms were manipulated using the Cool Edit 2000 software from Syntrillium Software running on an Intel Pentium II under Windows 98. In all cases the waveforms are in CD format (stereo linear PCM, 44,100 samples per second, 16 bits/sample). All references to power are relative to a full-scale sine wave.

Audio Masking

It is well known that humans have a hard time noticing the presence of low levels of harmonics of a tone in the presence of a strong signal at the fundamental frequency. The first three signals illustrate this principle.

T1 This is pure tone at 220 Hz (A below middle C) lasting for 4 seconds. The waveform was generated with maximum amplitude of –3.2 dB to avoid any clipping even after manipulation or the addition of harmonics. Here are statistics calculated from this wav form.

	Left	Right
Min Sample Value:	-22670	-22670
Max Sample Value:	22670	22670
Peak Amplitude:	-3.2 dB	-3.2 dB
Possibly Clipped:	0	0
DC Offset:	0	0
Minimum RMS Power:	-3.21 dB	-3.21 dB
Maximum RMS Power:	-3.21 dB	-3.21 dB
Average RMS Power:	-3.21 dB	-3.21 dB
Total RMS Power:	-3.21 dB	-3.21 dB

Using RMS Window of 50 ms

T2 This is a pure tone at 440 Hz (the first harmonic of T1 or A above middle C) also lasting for 4 seconds and at a maximum amplitude of –0.1 dB. Below are the statistics.

	Left	Right
Min Sample Value:	-32393	-32393
Max Sample Value:	32393	32393
Peak Amplitude:	-.1 dB	-.1 dB
Possibly Clipped:	0	0
DC Offset:	0	0
Minimum RMS Power:	-.11 dB	-.11 dB
Maximum RMS Power:	-.11 dB	-.11 dB
Average RMS Power:	-.11 dB	-.11 dB
Total RMS Power:	-.11 dB	-.11 dB

Using RMS Window of 50 ms

T3 is T1 followed by T1+T2/100. That is this T1 for 4 seconds followed by T1 with 1% harmonic distortion for 4 seconds. A harmonic analysis of the waveform (using the FFT capability of Cool Edit) shows the 440 Hz tone down 40 dB from the 220 Hz tone. T1 and T2 were combined using the Cool Edit mix paste function with the mix level set to 1 on a scale of zero to 100. The Cool Edit mix paste function was used for all other combinations of waveforms described in this memo. However, as with this example, various checks were made of the resulting levels to assure that the results are as represented.

Statistics below.

	Left	Right
Min Sample Value:	-22674	-22617
Max Sample Value:	22674	22732
Peak Amplitude:	-3.2 dB	-3.18 dB
Possibly Clipped:	0	0
DC Offset:	0	0
Minimum RMS Power:	-3.21 dB	-3.21 dB
Maximum RMS Power:	-3.21 dB	-3.21 dB
Average RMS Power:	-3.21 dB	-3.21 dB
Total RMS Power:	-3.21 dB	-3.21 dB

Using RMS Window of 50 ms

T4 is T1 followed by T3. That is T4 consists of 4 seconds of 220 Hz followed by 4 seconds of 220 Hz with 1% harmonic distortion. There is a slight discontinuity or pop

right at 4 seconds. A spectrum analyzer picture of the waveform as it plays shows the 440 Hz tone appearing right at 4 seconds at the –40 dB level. I cannot hear it though.

T5 is just like T4, except that the added signal during the last second 4 seconds is at 2090 Hz. 2090 Hz lies right between the 9^{th} and 10^{th} harmonics of 220 Hz and is a long ways away from 220 Hz. There should be very little masking. When I listen to this waveform I can hear the 2090 tone pop in at 4 seconds and stay for the rest of the time.

T6 is T1 plus noise 30 dB down from the 220 Hz tone. The noise is white noise generated using the waveform generation capabilities of Cool Edit. The noise has a flat spectrum when passed through the FFT spectrum analyzer. The 30 dB level is selected because it offers better performance that does OET's standard of 3% added THD when applied to an amplifier with 1% THD. (Seven of the 16 receivers tested by NPR/CEMA had THD of 0.9 dB or more.) A total of 4% THD corresponds to a 25/1 SNR (voltage) or 20 log(25) = 28 dB SNR. Thus, if 2^{nd} adjacent channel interference generated noise and distortion at the –30 dB level into a receiver with 1% THD, the OET test would judge that receiver did not fail by the 3% added THD criterion. This example is probably a little flawed. Unless you are using very good speakers, most of the noise is at high frequencies that will not be reproduced well or that cannot be heard by many people. That is, this example uses unweighted noise.

T7 is a 40 second clip of from the beginning of Mozart's Symphony No. 25 in G minor (K183). This is a quiet passage, so it is more susceptible to noise and interference. It was taken as a PCM file right off the CD. The statistics are

	Left	Right
Min Sample Value:	-5727	-5308
Max Sample Value:	5150	5124
Peak Amplitude:	-15.15 dB	-15.81 dB
Possibly Clipped:	0	0
DC Offset:	-.002	-.002
Minimum RMS Power:	-69.23 dB	-72.7 dB
Maximum RMS Power:	-20.41 dB	-21.86 dB
Average RMS Power:	-29.16 dB	-31 dB
Total RMS Power:	-27.85 dB	-29.77 dB

Using RMS Window of 50 ms

As you can see it is indeed a quiet passage. But, not everybody listens to hard rock. **T8** is that same passage with noise at the –30 dB level. Below are the statistics of the noise waveform. Notice that the noise power is really about –31.2 dB, a little bit lower than –30 dB. This noise was generated using the Cool Edit waveform generation feature with the amplitude set on the lowest level. It was then mixed with the Mozart at a gain setting of 100. Using the gain setting of 100 and mixing with an empty wave results in a waveform with the same statistics as the noise waveform.

	Left	Right
Min Sample Value:	-1903	-1903
Max Sample Value:	1895	1899
Peak Amplitude:	-24.71 dB	-24.72 dB
Possibly Clipped:	0	0
DC Offset:	-.004	0
Minimum RMS Power:	-31.7 dB	-31.65 dB
Maximum RMS Power:	-30.72 dB	-30.78 dB
Average RMS Power:	-31.19 dB	-31.19 dB
Total RMS Power:	-31.19 dB	-31.19 dB

Using RMS Window of 50 ms

T9 is a 40 second selection of Johnny Cash (from the beginning of Ghost Riders in the Sky). This is not a quiet passage, in the sense that the levels rise near the maximum from time to time. Average power is about 20 dB higher than the Mozart. Below are the statistics.

	Left	Right
Min Sample Value:	-31653	-31246
Max Sample Value:	30532	30493
Peak Amplitude:	-.3 dB	-.41 dB
Possibly Clipped:	0	0
DC Offset:	.001	0
Minimum RMS Power:	-23.53 dB	-21.63 dB
Maximum RMS Power:	-5.66 dB	-6.78 dB
Average RMS Power:	-12.4 dB	-12.31 dB
Total RMS Power:	-11.88 dB	-11.9 dB

Using RMS Window of 50 ms

T10 is a mix of the Mozart with the Johnny Cash down by 30 dB. The Johnny Cash cut was processed by the Cool Edit Transform/Amplify/10 dB cut command three times in a row. The statistics of the resulting waveform were

	Left	Right
Min Sample Value:	-1003	-998
Max Sample Value:	971	972
Peak Amplitude:	-30.28 dB	-30.33 dB
Possibly Clipped:	0	0
DC Offset:	0	0
Minimum RMS Power:	-53.53 dB	-51.6 dB
Maximum RMS Power:	-35.66 dB	-36.75 dB
Average RMS Power:	-42.4 dB	-42.28 dB
Total RMS Power:	-41.89 dB	-41.87 dB

Using RMS Window of 50 ms

Clearly, the new waveform is 30 dB down from the old. It was then mixed with the Mozart using the paste mix function at the 100 level.

T11 is here to show that there is no bias against country music. It is the Johnny Cash cut with white noise at –30 dB (-31.2 really).

T8, T10 and T11 are audio signals that would be regarded as undiminished in quality by the NLG and OET test results. That is, their test methods would not indicate any loss to consumers if 2nd-adjacent channel interference drove audio performance from 50 dB SNR to these levels.

T12, T13 and T14 show a worst case interpretation of the FCC's rules. The NPR/CEMA test showed a receiver with 3.5% THD. (Average of left and right channel values of 3.4 and 3.6%).

T12 is 4 seconds of 220 Hz followed by 4 seconds of 220 Hz plus 440 Hz at the 6.5% level. This illustrates 3% added THD for the receiver with the highest THD in the NPR/CEMA tests. The added second harmonic is easily detected; after all it is only 23.7 dB down from the fundamental. I don't find it particularly objectionable, but it is clearly noticeable.

T13 is Ghost Riders with noise at the 4.4% level (-27.17 dB relative to a full scale sine wave, unweighted, note 4.4% is –27.13 but this section actually used –27.17). This would be regarded as unimpaired under the FCC's strictest criterion (1% added THD for a receiver with THD of 3.5%).

T14 is Ghost Riders with noise at the 6.4% level (-23.9 dB). This would be regarded as unimpaired under the FCC's more permissive criterion (3% added THD for a receiver with a THD of 3.5%).

Attachment A

DOCUMENT OFF-LINE

This page has been substituted for one of the following:

o An oversize page or document (such as a map) which was too large to be scanned into the ECFS system.

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